6.2-6.4 RDT&E Reviews
Stennis Space Center, MS
26-28 February 2013

Project: Modeling Sensing and Forecasting Ocean Optical Products for Navy Systems

PI: Sherwin Ladner
Email: ladner@nrlssc.navy.mil
Phone: 228-688-5754

Performers: B. Arnone, J. Joliff, A. Weidemann, S. Derada, A. Quaid – NRL
B. Casey, J. Bowers - QNA

Customer POCs – Ken Grembowicz, K. Matulewski, P. Lyon, P. Flynn - NAVO

Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems

Objectives

Provide naval operations with a real time and forecast characterization of the battlespace used to produce warfare performance surface for ocean optical and visible detection

1. Forecast coastal ocean optical properties including water clarity, horizontal and vertical visibility for visual detection vulnerability and lidar penetration depth (ALMDS).
2. 3D optical volume (nowcast/forecast) derived by assimilating gliders, satellite and ocean models to define the 3d optical structure.
3. Performance surfaces supporting underwater laser imaging systems (AQS/EODES), airborne laser systems (ALMDS), active and passive EO bathy systems, and diver operations (visibility/vulnerability).

Requirements and Capabilities

CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 Hi Res Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare

- Predict and forecast the 2D/3D optical environment
- Fusion of environment data for impact assessments
- 4 d coherent picture of the coastal environment
- (Naval Capability Based Assessment for oceanography for 21st Century EXW) Oct 2009)
- TACMEMO under development for performance surface for active EO Identification CNO(N841A) 762-0601; 16 October 2009
- METOC Environment Initial Capabilities Document (ICD) define performance field for MIW imaging system

FY12/13 Accomplishments/Challenges/Issues

1. 3D BioCast v1.0 testing and integration into TODS completed.
2. 3D BioCast v1.0 upgrade for high resolution bathymetry anomalies and surface flow field correction in shallow upper layer (Eckman)
3. 3D BioCast v1.0 forecast testing/automation completed using multiple satellite and model resolutions.
4. BioCast v1.0 VTR Draft 1 complete; Delivery and installation scheduled for March

Issues: Discovered problems with high resolution bathymetry anomalies and surface flow fields (top Eckman layer –shallow – sigma z). Required re-running of 10 month validation time series (MSB Test Bed). Validation delayed. AOPS transition.

FY13 Tasks for 3D Optical Volume (3DOG) transition / VTR starting in Q2FY13.

Issues: Navy funding cuts for MIW exercises? No FY12 MIW exercise participation – Not Available.

Funding

($K)	FY12	FY13	FY14	FY15
JPSS - cal val	200	200	200	200
6.2 Subsurface Optics	565			
6.2 Bio-Optical Feedback	650	650		
6.2 Algortihm ensemble	500	500		
Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems	**150**	**235**	**290**	**105**

Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems

Project Major Milestones for FY12-FY15

Tactical Ocean Display System (TODS)	FY12				FY13				FY14				FY15			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
(1) Forecast Optical Properties (OpCast-2D FY11 / BioCast-3D FY12)				**V**	**O**									**V2**	**O**	
(2) 3D Optical Nowcast (3DOG) w/ AQS-24 System Performance										**V**	**O**					
(3) Exercises / Demonstrations					**D**		**D**			**D**						

Milestones indicate **V**TR panel-accepted and **O**PTEST

BioCast v1.0: 95% complete , Planned Transition / VTR Q2FY13 (March)

3DOG v1.0: 50% complete , Planned Transition / VTR Q2FY14.

Possible delay due to MIW asset / optical glider availability in planned exercises. APS Transition Q1FY13.

BioCast v2.0: 20% complete , Planned Transition / VTR Q1FY15

Modeling, Sensing and Forecasting Ocean Optical Products for Navy Systems
Transition Plan Summary

1. **SUMMARY CONOPs:**
   The TODS system will reside with NAVO NP33 automatically producing NRT high resolution integrated oceanographic products to support a variety of Navy missions. TODS will primarily be used to support MIW exercises/operations but also supports a variety of shallow water missions *(NSW, ISR, ASW and EXW)*. TODS currently provides 2D optical forecasts. In FY14, it will provide 3D optical forecasts and MIW system performance products. *POC's Kenneth Matulewski (NP3), Paul Lyon (NP3), Ken Grembowicz (NP3), Ron Betsch (NP6)*

2. **CAPABILITY REQUIREMENTS BASIS:**
   - This project supports CNO validated requirements CINC OCEN 91-06 Ocean Prediction Models, LITT OCEN 93-06 High Resolution Surface Current Predictions, USMC 93-01 Littoral Sea Environment and addresses needs outlined in the Concept of Operations for Naval Oceanography Support to Expeditionary Warfare.

3. **INPUTS:**
   - Satellite ocean color **imagery** (MODIS-Aqua, MERIS, VIIRS, GOCI, and future JPSS)
   - physical and optical **glider data** (quality controlled), BSP/AEP data, numerical **models** (NCOM, RELO)

4. **OUTPUTS / PRODUCTS:** Outputs will advance NRT high resolution fused oceanographic products to support a variety of shallow water naval missions *esp. MIW*.
   - a 2D/3D forecast of coastal ocean optical properties for the performance surface
   - laser imaging systems performance surface (such as the AN/AQS-24), swimmer performance surface (visibility and vulnerability)
   - a performance surface to support deployment of active and passive EO bathymetry systems (e.g. CHARTS)

5. **ACCEPTANCE CRITERIA:**
   - TECHEVAL at NRL with resulting VTR acceptance at NAVO (during fleet MIW exercises comparing 24 hour forecasts to next day images and profile data not assimilated into TODS to model data including Case II waters (if available exercises permit). Validation Test Reports (VTR's) will include validation/data during real MIW fleet exercises, other Navy leveraged exercises and the Northern Gulf of Mexico Test Bed
   - Successful OPEVAL at NAVO that will involve installation and testing the transitioned software on NAVO systems for a 2 month period.

Outline

- **TODS Overview (BioCast, 3D Optical Volume, AQS System Performance)**
- **Optical Forecast Advection Software Upgrade (BioCast v1.0)**
  1. BioCast overview
  2. Improvements over OpCast (Currently @ NAVO)
  3. Validation Results (VTR)
- **Exercise update for MIW Demonstrations/ Testing / Evaluation**

  NAVO POC – Ken Matulewski

  1. *MIW Harp Demonstration Location TBD (Summer/Fall 2013) – Need another for end-to-end TODS system performance demonstration / evaluation*
  2. NAVO LBS-G Test Panama City (February 2013) Test for future exercises. 3 NAVO Gliders – Initial Evaluation – Optics data looks good (3DOG Validation).
  3. Trident Warrior ASW US East Coast / Chesapeake Bay Virginia (July 2013) – 1 NRL Optics Glider (ONR Funded) & 2 NAVO LBS Optics Gliders. Planning underway. 3DOG Validation

  No MIW Demonstration/Exercise participation in 2012

Overview of TODS Components

1) Display 2) OPCAST 2D / BioCast 3D
3) 3D and Performance Surfaces

NAVO Operational Inputs

Satellite Data Processing (AOPS v4.0)
NP3

RELO NCOM MODELS
lowcast / Forecas
NP3

LAGER
Glider Physics & Optics
Auto & Manual QC Software
(FY11)
NP3 GOC

OpCast 2D (FY11)
ioCast 3D (FY13/15)
Advection Software

Optimization
Physical-Optical Coupling

Utilities
Post processing
Conversions optics
Interpolation

3D Optics Generator (3DOG)
FY14

Performance Surfaces
- Diver Visibility/
- Vulnerability
- AQS-24
- ALMDS

FY14

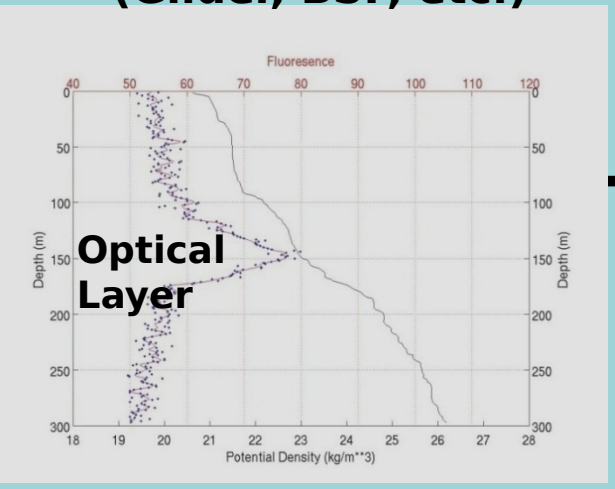
Real-Time Visualization/Display of Nowcast/Forecast Products

- **Fusion of Satellite and Model – provides real-time visual display interface for time series animations (pan + zoom)**
  - **MODIS, SEAWiFS, MERIS, OCM, NPP, AVHRR satellite imagery**
    (diver vis, beam attenuation (c), laser

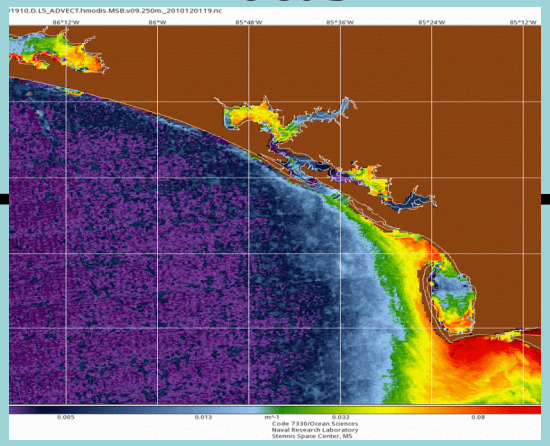
TODS: Fusion of Glider Profiles, Satellite and Numerical Models to support AQS24

Operations

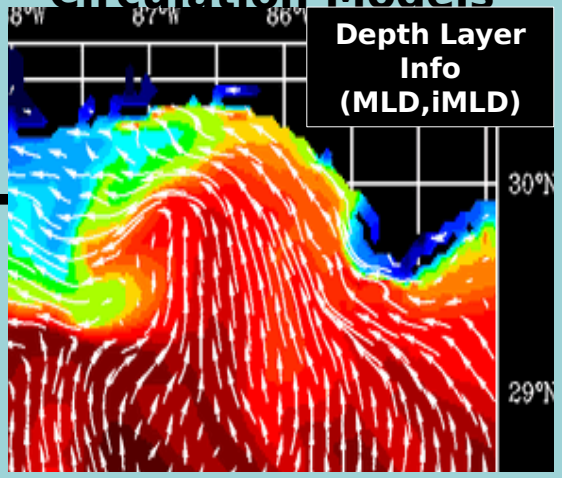
Vertical Optical Profiles (Glider, BSP, etc.)



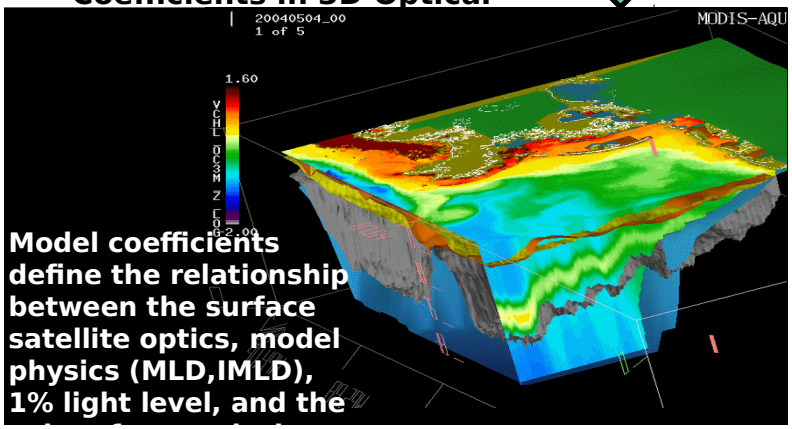
Nowcast / Forecast Satellite Optics BioCast



Nowcast / Forecast Circulation Models



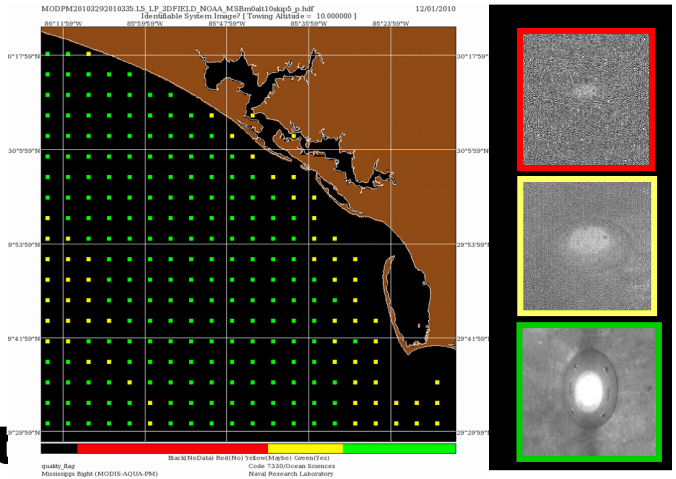
Insitu Optics Used for Tuning Coefficients in 3D Optical



EODES

Nowcast/Forecast Performance Surfac

Image Quality & Optimal System Towing Altit



ptical Volume/Profiles & 3D Diver Visibilit

BioCast Overview

COMBINE

Combine Satellite Images with Ocean Circulation Model Results

Step 1 – Map flow field information (u,v m s^{-1}) to user-specified grid (i,j,k)

Step 2 – Iteratively constrain the mapped flow field to continuity

Step 3 - Three-Dimensional Advection Calculation

Step 4 – Blend results with next-day image

Step 5 – repeat (1-4)

BioCast Advantages

COMBINE

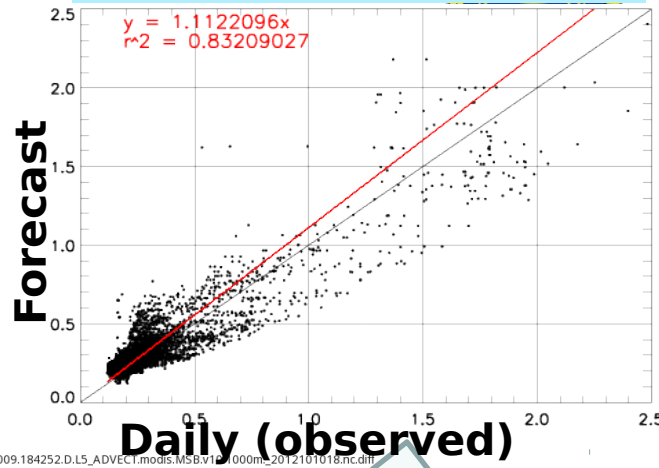
- Input/Output can be 2-D or 3-D (OpCast 2D Only)
- Computationally Efficient
- Conservation of mass within the domain (no spurious sources/sinks)
- Originally designed for Marine Ecosystem Modeling – i.e., source/sink terms may be added

TODS – Optical Forecast Operations (BioCast v1.0)

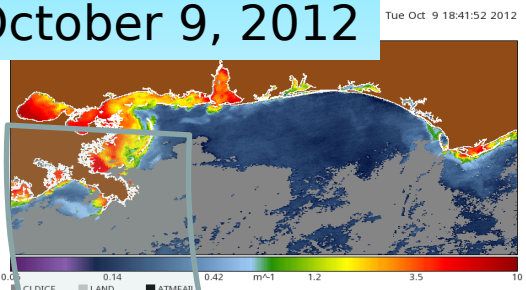
Beam-c @531nm

- r^2 0.83
- Y = 1.1122x

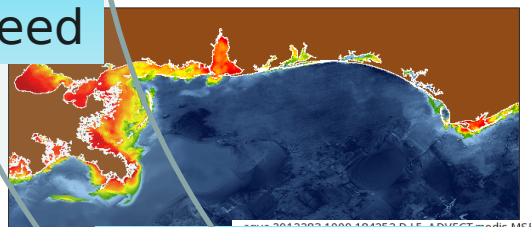
Forecast vs Measured



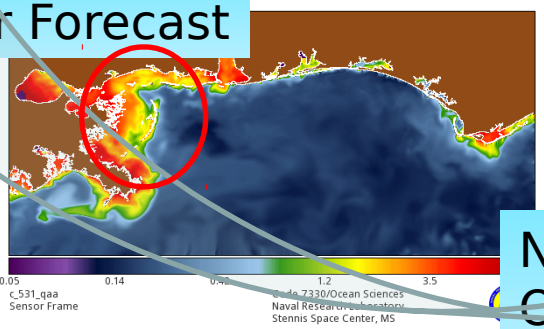
Today's Image October 9, 2012



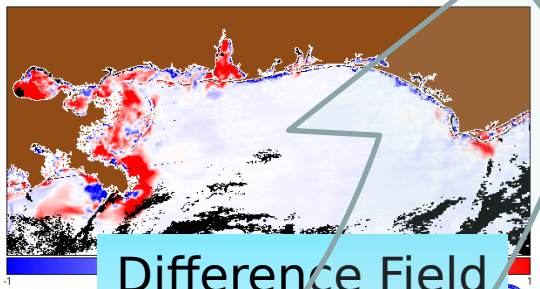
Seed



24 Hr Forecast



Metrics For VTR



Difference Field

Next Day's Image October 10, 2012

Optical Forecast Evaluation
2D OpCast vs New 3D BioCast

OpCast (Currently @ NAVO) vs. BioCast (Q2FY13)

OpCast = Surface Only Advection
BioCast v1.0 = 3D Advection (Homogeneous Volume)

Forecast runs made for a 10 month (December 2011 – October 2012) image sequence using MODIS Aqua 1KM for the MissBight Test Bed.

SEED/initialization field created using:

1. Today's Satellite Image
2. Invalid pixels filled with previous day's 24 hour forecast

Validation: 24 Hour forecast are compared with next day's image (valid pixels only)

Assumptions: Biological growth decay and particle source/sink neglected for forecast period (conservative).

Note: If the area interest is cloudy for n days, then the SEED/ initialization image can be filled with a forecast from 1 to n days.

BioCast Validation
NGOM Test Bed
(MissBight)

Imagery Combined
w/ Circulation Models

OpCast/BioCast
Comparison

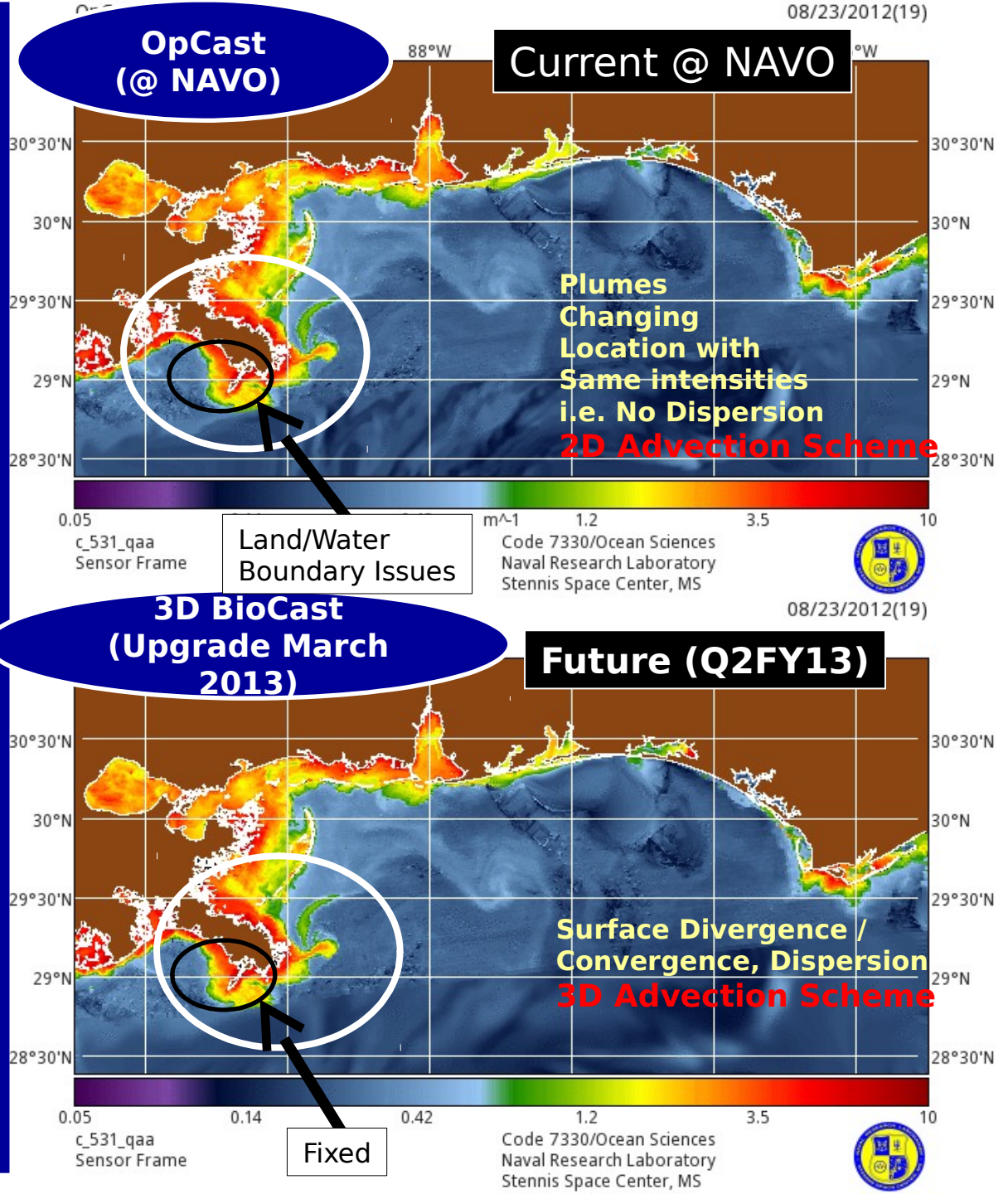
24 Forecast Animation
@ 3 Hour Time Steps

Satellite: MODIS Beam-c1km
Model: RELO-NCOM
AMSEAS 3km

August 23, 2012

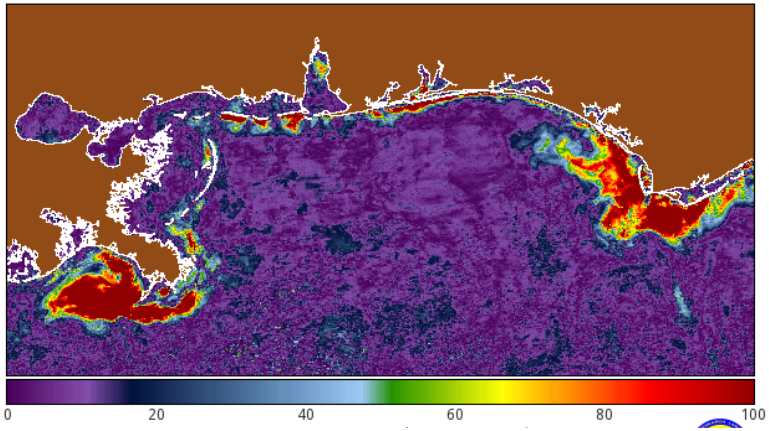
BioCast/TODS
Integration Complete
Validation Underway

Validation Dataset
BioCast & OpCast
December 2011 – October 2012

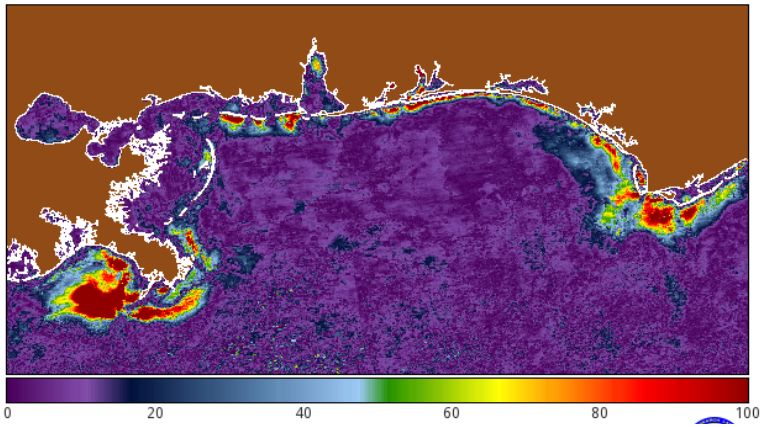


10 Month Mean Forecast Statistics
(December 2011 – October 2012)
MODIS-Aqua Beam Attenuation Coefficient (c) @ 531nm

OpCast (Mean Absolute % Error)

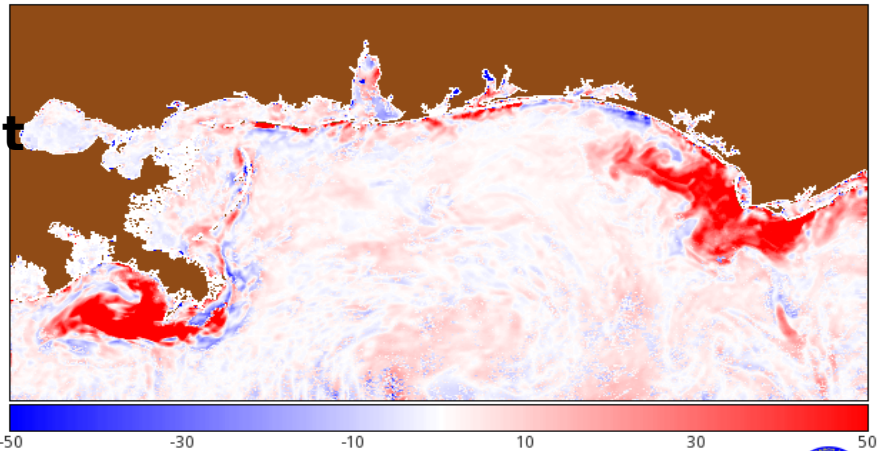


BioCast (Mean Absolute % Error)



$$MAPE = \left| \frac{c(forecast) - c(measured)}{c(measured)} \right| * 100$$

Difference OpCast – BioCast



Red = BioCast performs better

White = OpCast & BioCast are similar

Blue = OpCast performs better.

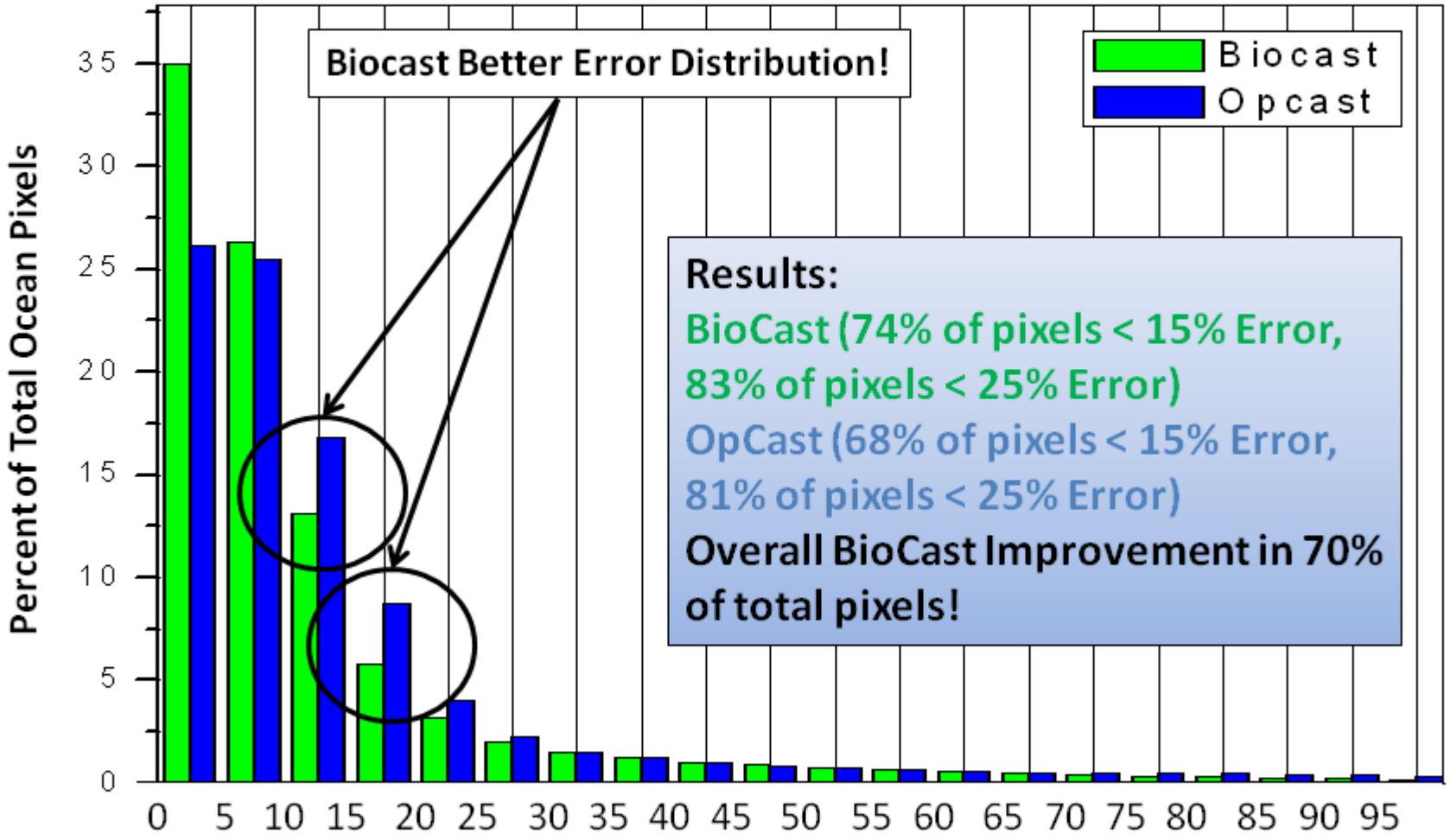
Geometric Mean

BioCast vs Opcast (December 2011 – October 2012)

24 Hour Forecast

ln(Mean(24 Hour Forecast)) – ln(Mean (Next Day's Image))

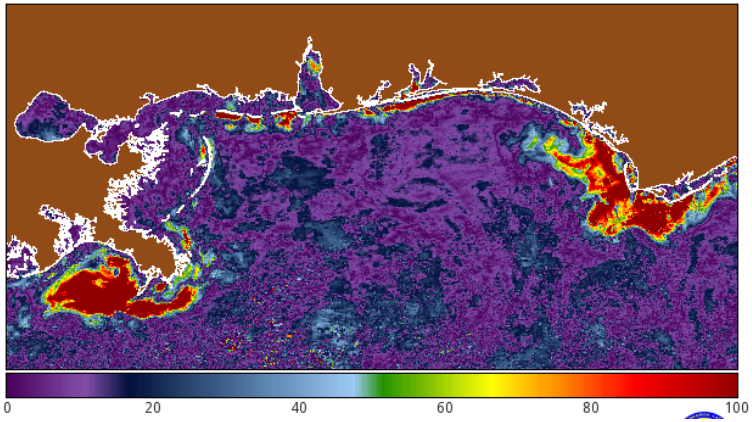
Beam Attenuation (c) @ 531nm



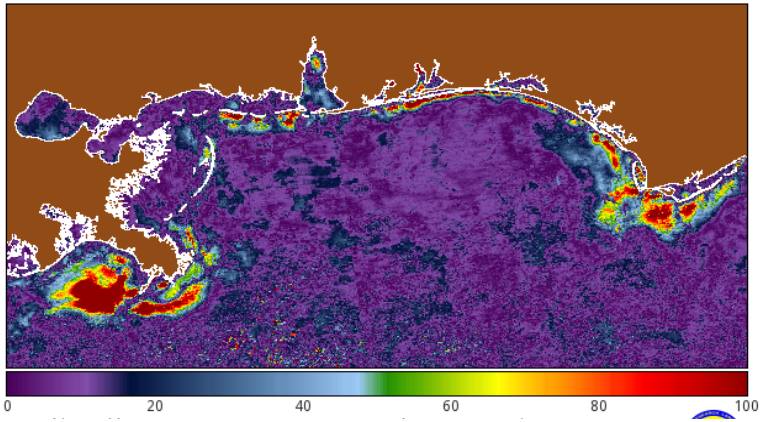
$$\text{MAPE} = \left| \frac{c(\text{forecast}) - c(\text{measured})}{c(\text{measured})} \right| * 100$$

10 Month Mean Forecast Statistics
(December 2011 – October 2012)
MODIS-Aqua Backscattering Coefficient (c) @ 531nm

OpCast (Mean Absolute % Error)

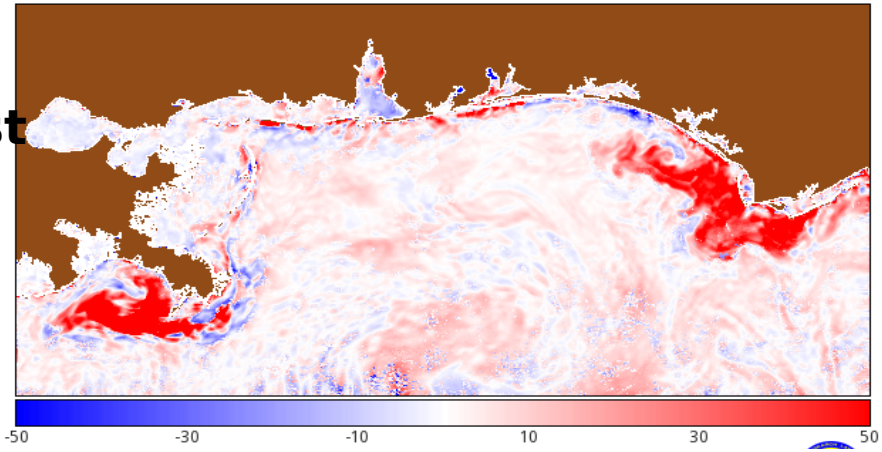


BioCast (Mean Absolute % Error)



$$MAPE = \left| \frac{c(forecast) - c(measured)}{c(measured)} \right| * 100$$

Difference OpCast – BioCast



Red = BioCast performs better

White = OpCast & BioCast are similar

Blue = OpCast performs better.

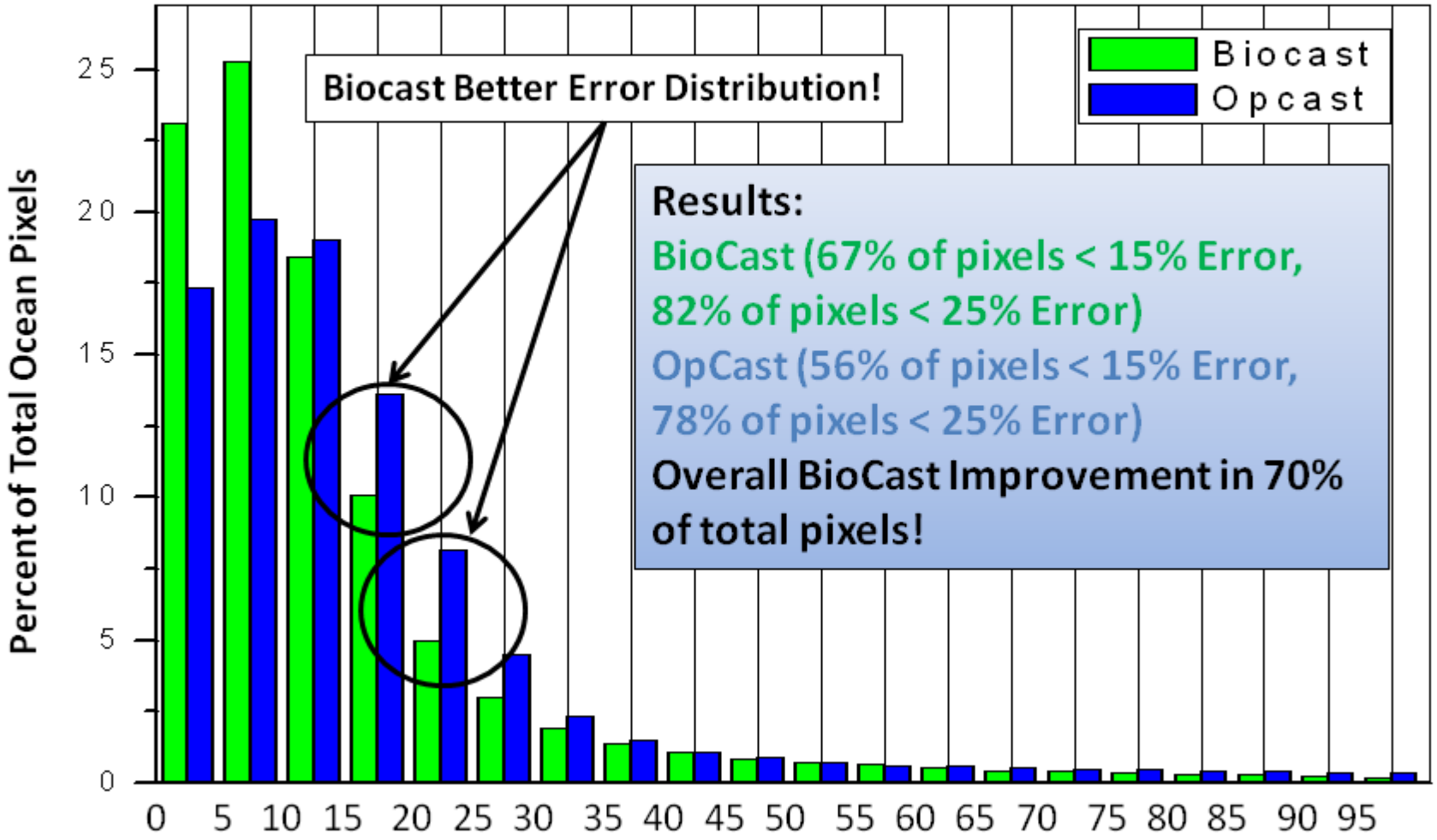
Geometric Mean

BioCast vs Opcast (December 2011 – October 2012)

24 Hour Forecast

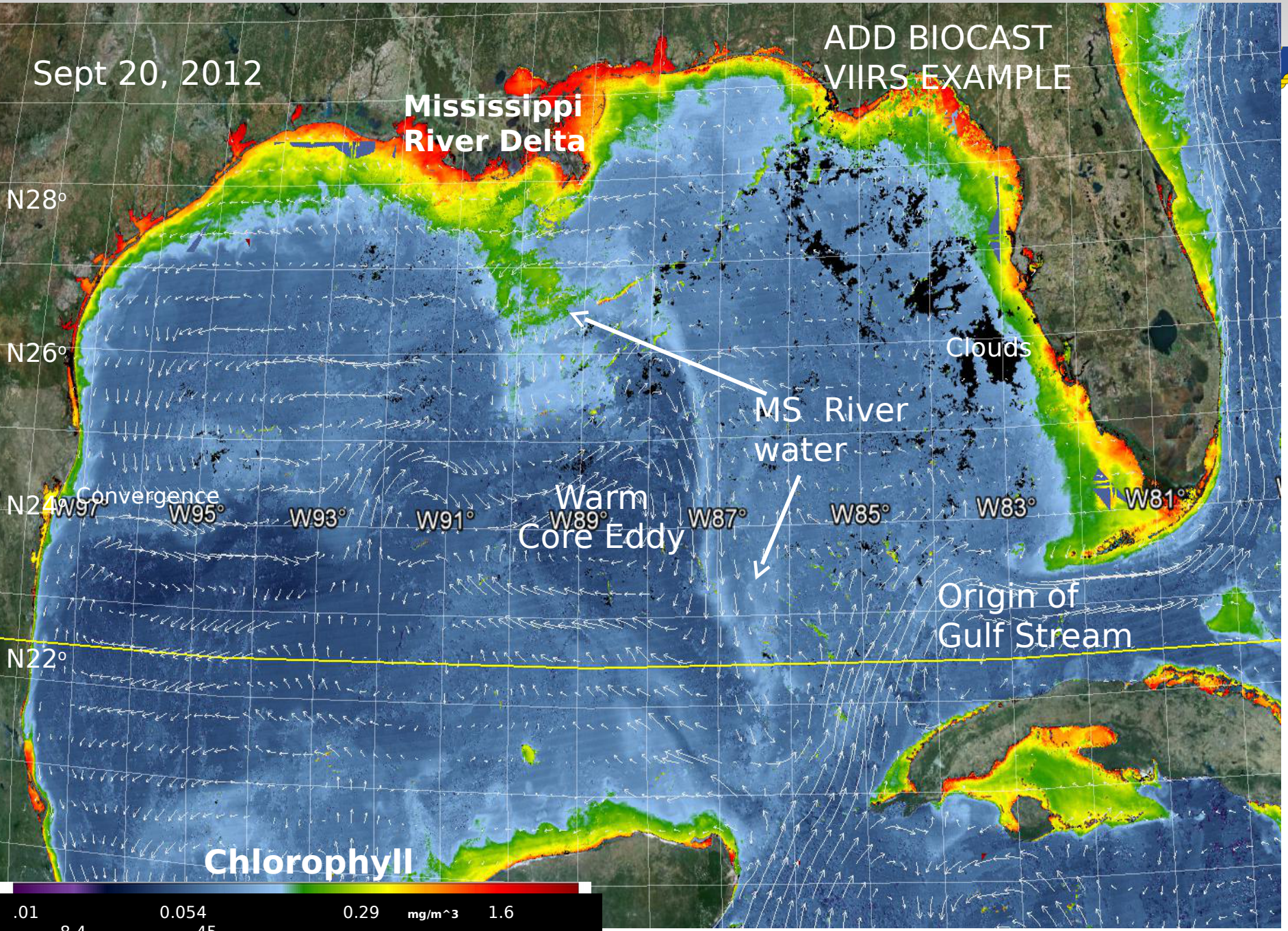
ln(Mean(24 Hour Forecast)) – ln(Mean (Next Day's Image))

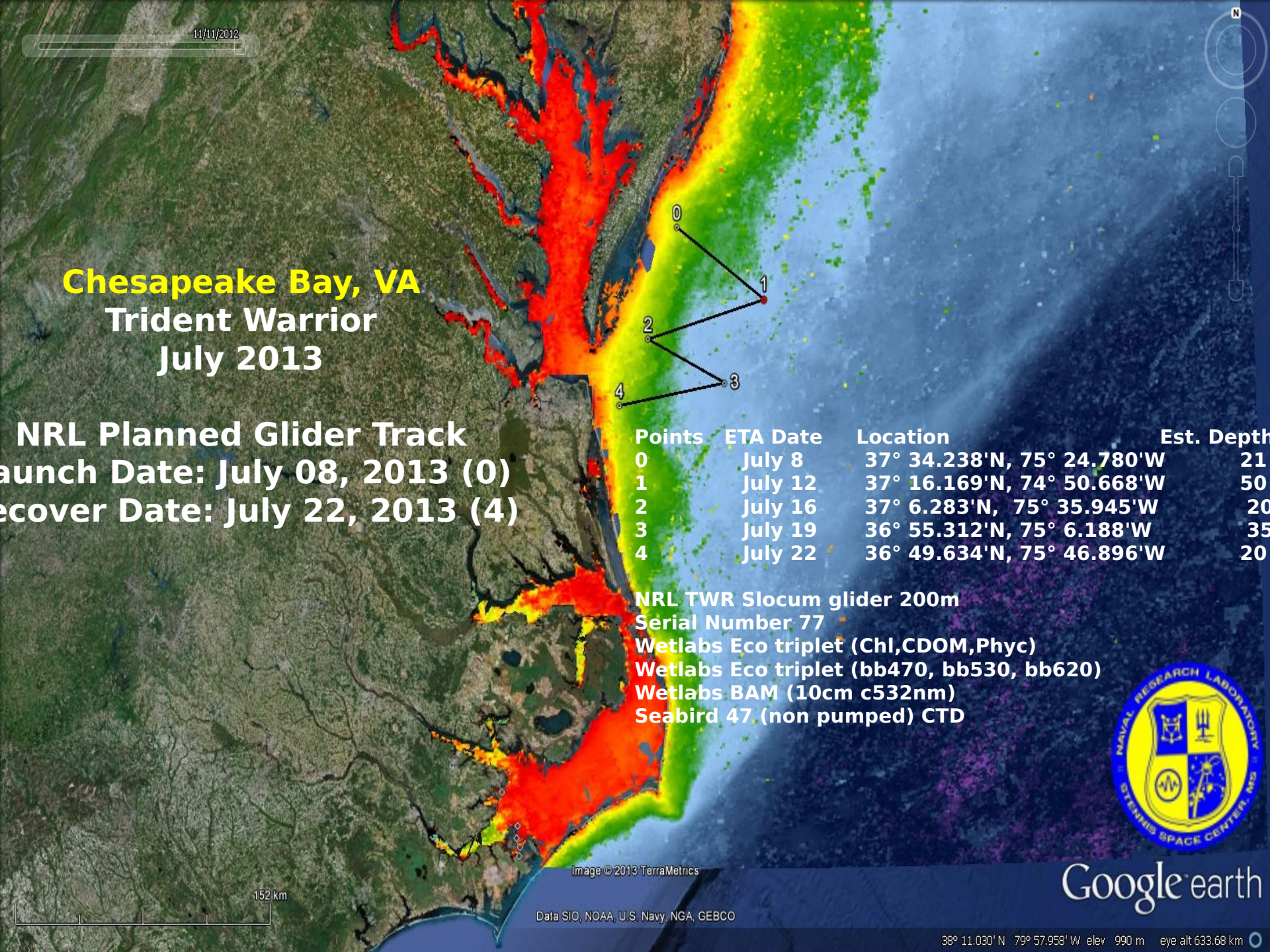
Backscattering (bb) @ 531nm



$$\text{MAPE} = \left| \frac{c(\text{forecast}) - c(\text{measured})}{c(\text{measured})} \right| * 100$$

VIIRS - Surface Chl – MSB Test Bed – TODS Integration &




11/11/2012
Chesapeake Bay, VA
Trident Warrior
July 2013
NRL Planned Glider Track
aunch Date: July 08, 2013 (0)
ecover Date: July 22, 2013 (4)
0
1
2
3
4
Points ETA Date Location Est. Depth
0 July 8 37° 34.238'N, 75° 24.780'W 21
1 July 12 37° 16.169'N, 74° 50.668'W 50
2 July 16 37° 6.283'N, 75° 35.945'W 20
3 July 19 36° 55.312'N, 75° 6.188'W 35
4 July 22 36° 49.634'N, 75° 46.896'W 20
NRL TWR Slocum glider 200m
Serial Number 77
Wetlabs Eco triplet (Chl,CDOM,Phyc)
Wetlabs Eco triplet (bb470, bb530, bb620)
Wetlabs BAM (10cm c532nm)
Seabird 47 (non pumped) CTD
NAVAL RESEARCH LABORATORY
STENNIS SPACE CENTER, MS
Image © 2013 TerraMetrics
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
152 km
Google earth
38° 11.030' N 79° 57.958' W elev 990 m eye alt 633.68 km

Combine With Google Earth

Trident Warrior
July 13-18, 2013
US East Coast / Virginia

Exercise Objective: Utilize observations from unmanned air, surface, and undersea vehicles (UxVs) to assess the impact of in-situ observations on the representation and prediction of the Ocean Battlespace Environment and subsequent tactical impact on predictions of the electromagnetic (EM) propagation characteristics in the coastal marine atmospheric boundary layer.

Planned Observing Platforms:
5 days on-station R/V Knorr (AGOR-15) (sfc met, sst, current profiles, single station rawinsondes and sfc fluxes)
50 ScanEagle UAV Flight Hours (~10 sorties @50 Kts) (met profiles, sfc wave lidar)
4 Waveglider USVs (sfc met, sst, current profiles)
5 Scripps drifting wave buoys (sfc wave spectra)
1-2 NPS Flux Buoys (sfc met, sfc fluxes)
6-10 SLOCUM Seaglider UUVs (ocean temp, salinity, optical profiles)

R/V Knorr single station VHF/UHF/SHF/EHF radio range, power, SNR observations.

288 High density P-3 dropped AXBT observations before/during/after TW'13 Intensive Observation Period (IOP)

Trident Warrior
July 13-18, 2013
US East Coast / Virginia

NRL Objectives:

1. To provide real-time combined satellite (visible,optics) and model (surface currents, SSH, salinity) support to daily operation.
2. Use glider optical properties from the slocum gliders to tune and evaluate the 3D optical volumes from 3DOG.

Products Provided:

- Regional True Color (R,G,B) image from Aqua MODIS with the coincident model and glider track/position overlaid: NCOM 500m resolution surface currents, operational boxes, and glider tracks.

- Regional Sea Surface Temperature (SST) image in degrees Fahrenheit derived from Aqua MODIS with the same model and glider overlays.

- Regional horizontal diver visibility image in meters derived from Aqua MODIS with the same model and glider overlays.

- Daily update of glider cross-section plots for (temperature, salinity,

Summary

BioCast v2.0

- 3DOG volume input / 3D output
- Particle settling terms for improvement in coast optical transition areas
  w/ large gradients
- (Identified a need for the settling of particles out of turbidity plumes as they propagate into the coastal ocean. Future improvements by adding sinking and decay rate constants to simulate these processes and improve forecast accuracy of plume dispersion and movement)

6.2-6.4 RDT&E Reviews
Stennis Space Center, MS
26-28 February 2013

Questions?

FY14 1498 Container: Project

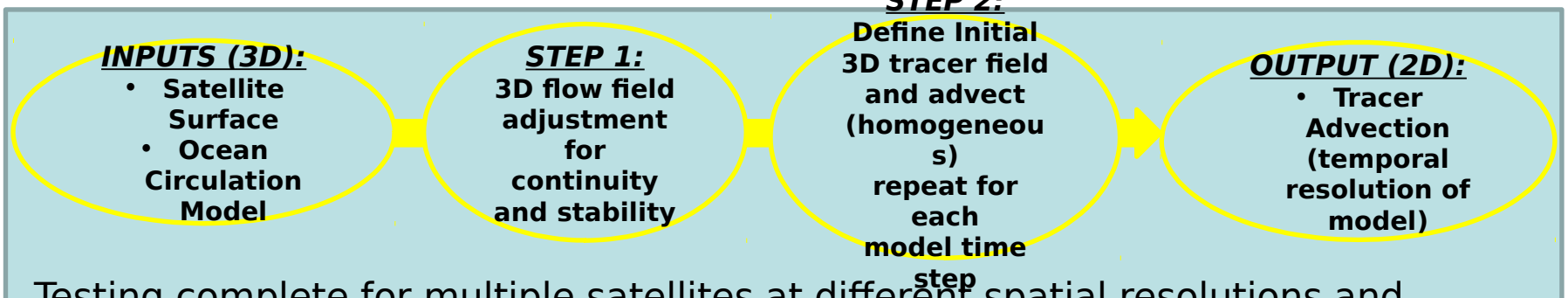
Tactical Ocean Data System (TODS)																
	FY13				FY14				FY15				FY16			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Major TRL Milestones	6	7	8	6	7	8		6	7	8						
1. Validate BioCast v1.0 3D Advection (2D Output)	-	C														
1. Transition BioCast v1.0 to NP3 w/ VTR and OPTEST Support to NAVO (NP331)		VTR	OPTEST													
1. Validate 3D Optical volume Generator v1.0 (3DOG)		S	-	-	C											
1. Transition 3DOG and Performance Surfaces (AQS-24/EODES) w/ VTR and OPTEST Support to NAVO (NP33)					S	VTR	OPTEST									
1. Validate BioCast v2.0 3D Advection (3D Output)						S	-	-	C							
1. Transition BioCast v2.0 to NAVO (NP3)									S	VTR	OPTEST					
1. Operational demonstrations of TODS Components (BioCast, 3DOG, AQS Performance Surfaces)	DEMO			DEMO			DEMO									
1. Monthly reports	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

Performer	FY13	FY14	FY15	FY16
Ladner (NRL)	68%	35%	33%	0%
Derada (NRL)	9%	0%	0%	0%
Jolliff (NRL)	4%	14%	0%	0%
McCarthy (NRL)	6%	28%	40%	0%
Casey (QNA)	6%	4%	0%	0%
Bowers (QNA)	7%	19%	27%	0%
Lovitt (QNA)	0%	0%	0%	0%
Funding required	$235K	$290K	$105K	$0K

BioCast 3D Advection Overview / Update

Preliminary comparisons with OpCast show forecast improvement
Integration into TODS Complete – Drop in replacement OpCast 2D Advection
Testing and Validation (VTR) underway

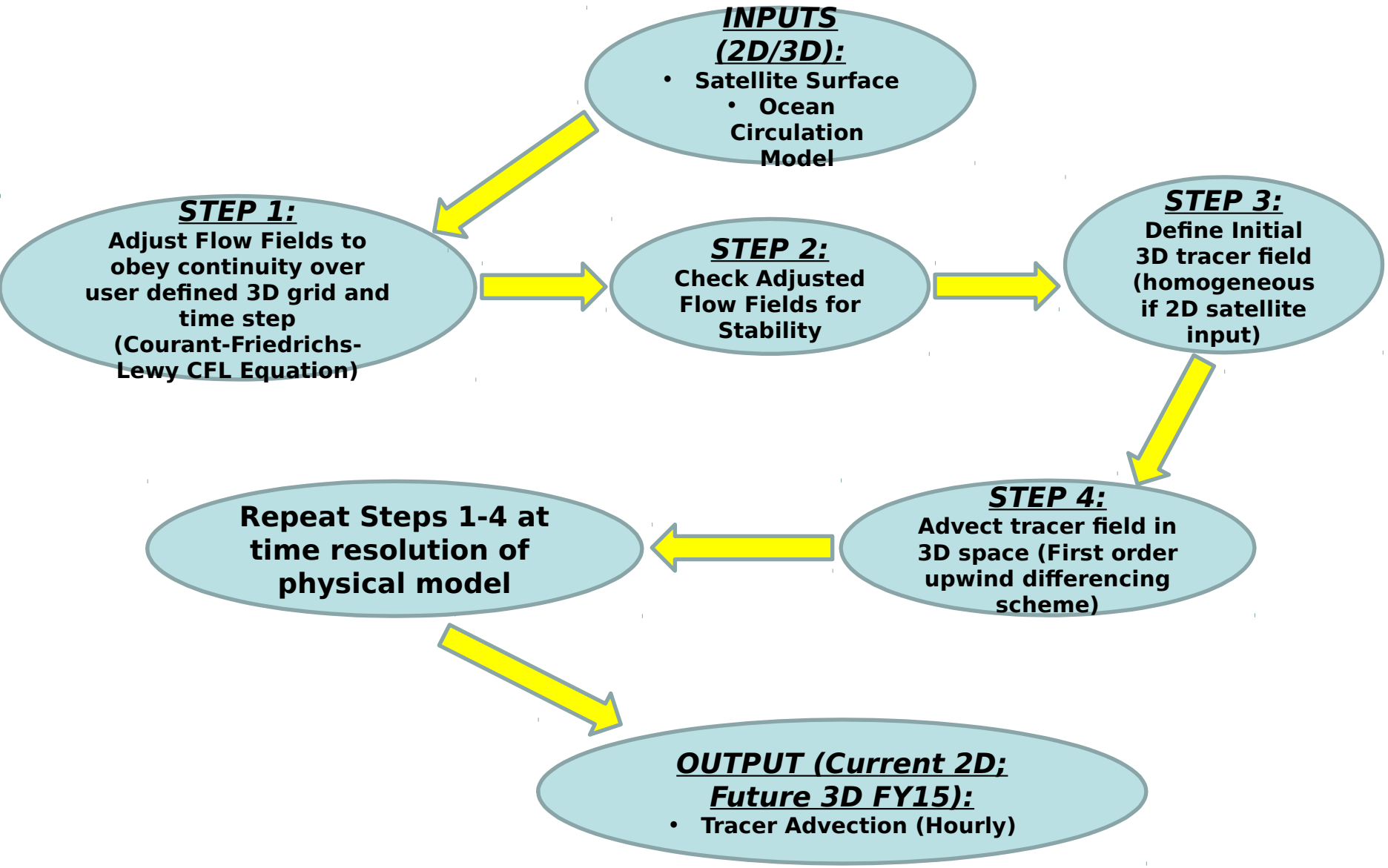
Transition to NAVO (NP3) w/ VTR FY 13 (Q2) – Replacement for OpCast v



Testing complete for multiple satellites at different spatial resolutions and multiple model resolutions:

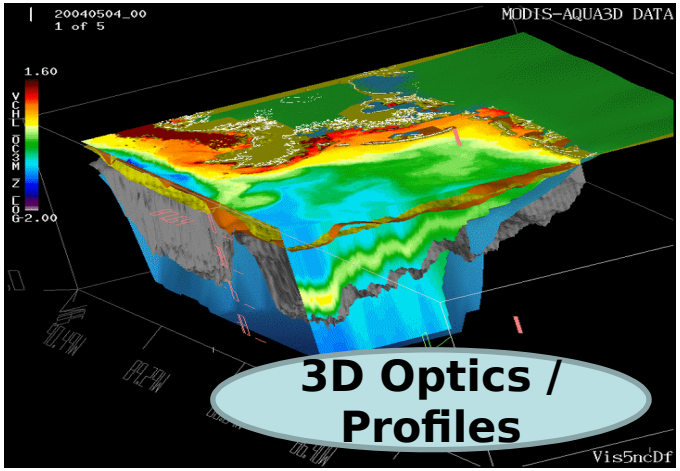
1. MissBight (real-time since September 01, 2011) - Operational
   MODIS 1KM w/ 3km RELO-NCOM AMSEAS (NAVO)
2. Chesapeake Bay (3 month test; September 01 – November 28, 2011)
   MODIS 250m w/ 500m RELO-NCOM CHESAPEAKE_MIW (NAVO)
3. Chesapeake Bay (1 day test; January 09, 2011) – *High Resolution Testing*
   HICO 100m w/ 500m NAVO RELO-NCOM CHESAPEAKE_MIW (NAVO)
4. Korean Sea / Yellow Sea (1 day test; May 13, 2011)
   Hourly Evaluation bb555nm
   GOCI 500m w/ 3km NAVO RELO-NCOM WPAC_2 (NAVO)

BioCast 3D Advection Overview & Flow Diagram

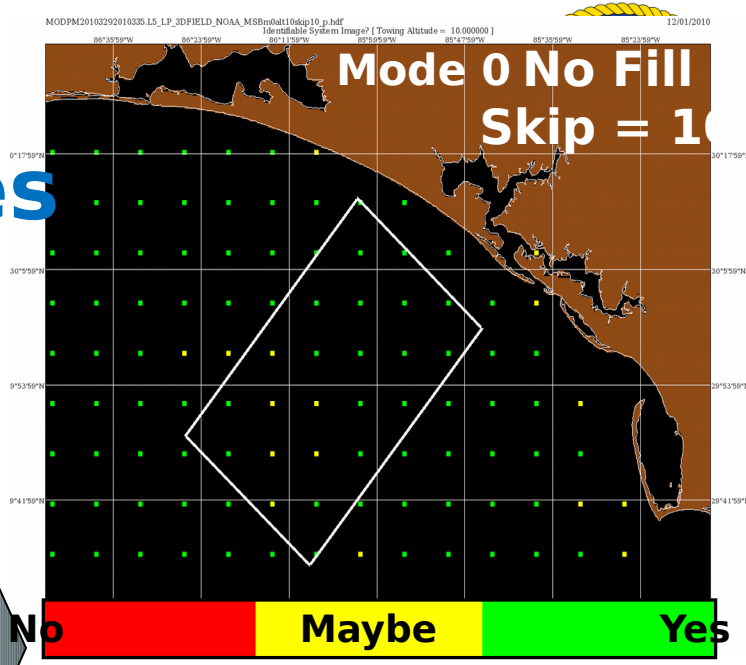


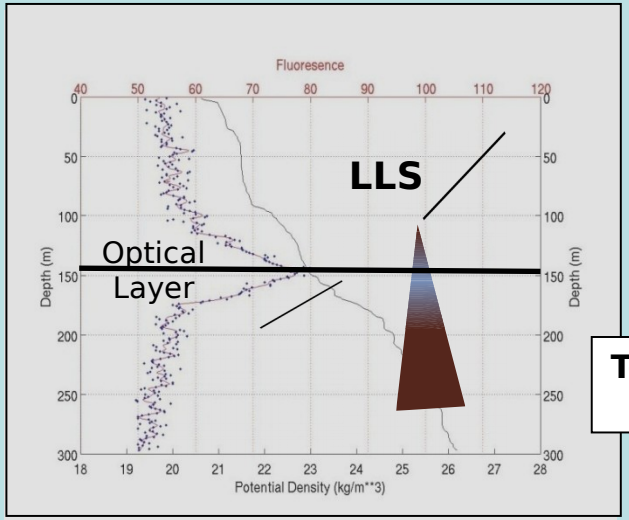
EO/AQS-24 Performance Surfaces

egional Battlespace Characterization



LASER Performance Model (EODES)

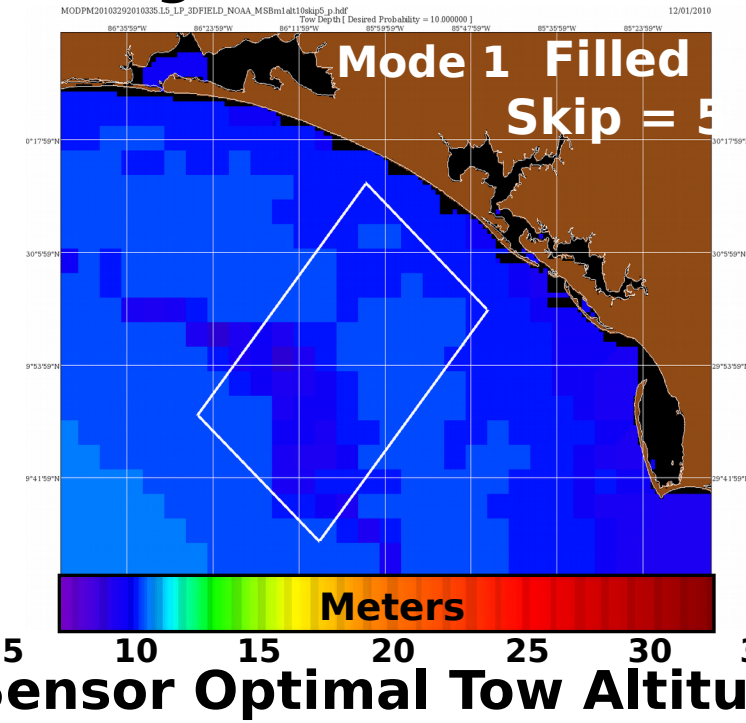




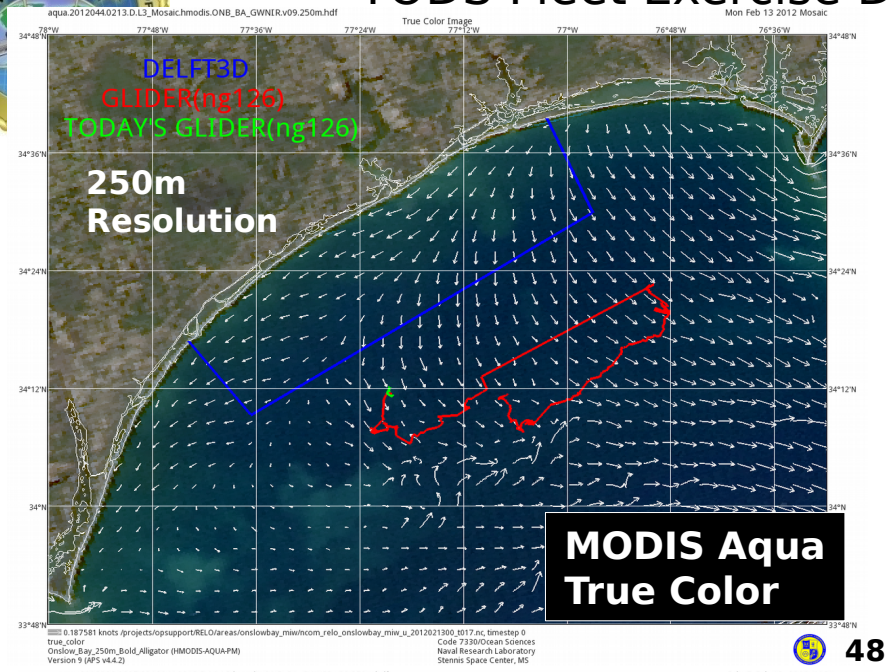
EODES Point Performance (BSP)

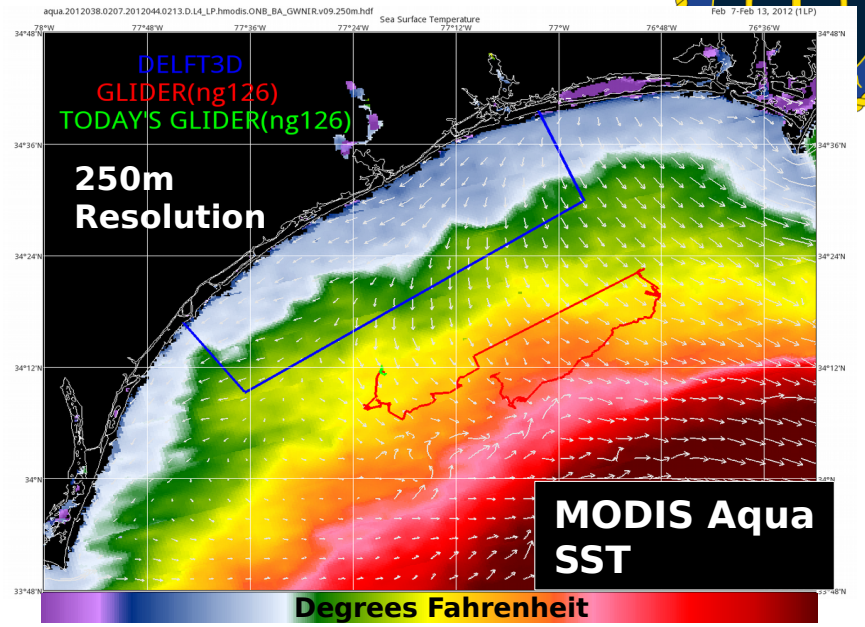
Tow Above/Below Optical Layer

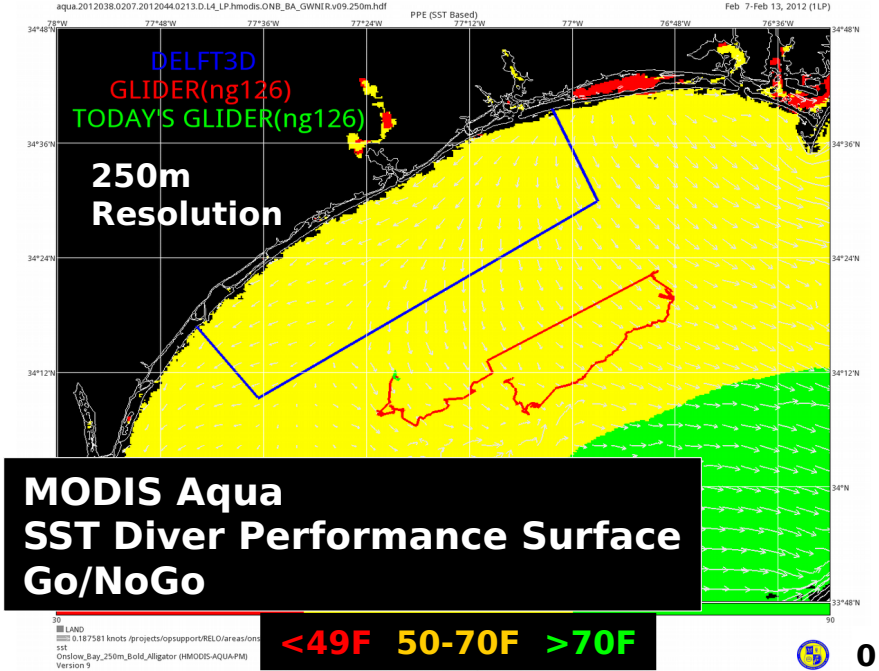
Target ID?

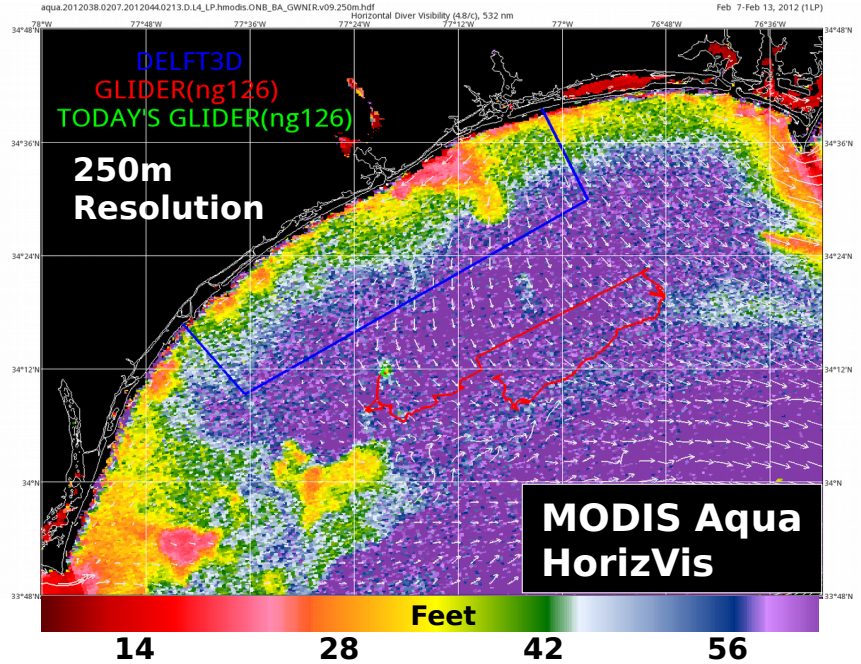


Bold Alligator ASW Amphibious
TODS Fleet Exercise Demonstration 2/13/12



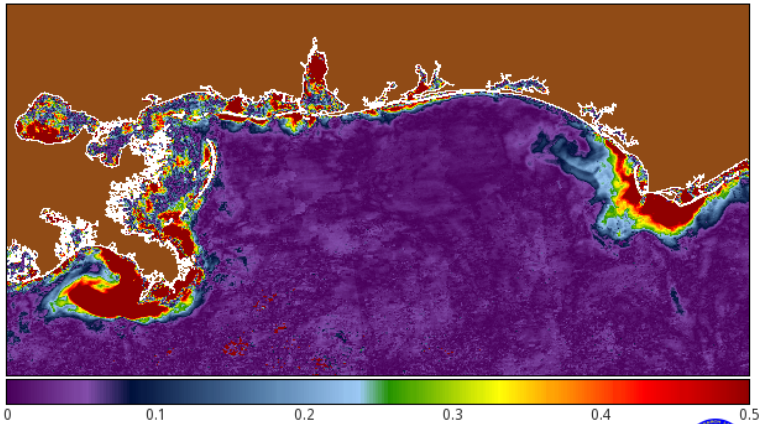




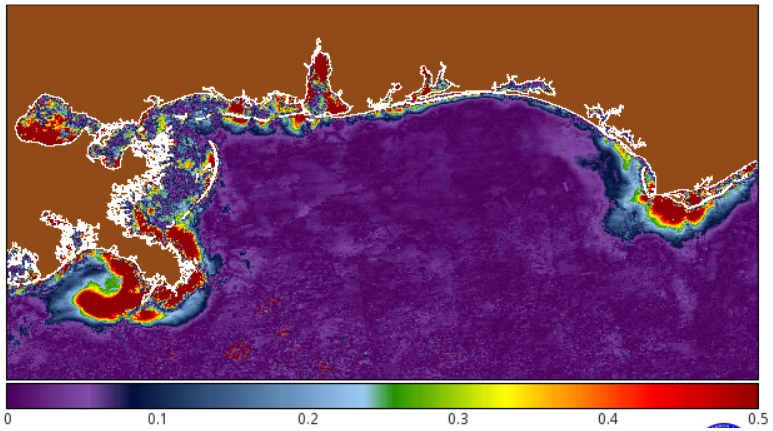


10 Month Mean Forecast Statistics
(December 2011 – October 2012)
MODIS-Aqua Beam Attenuation Coefficient (c) @ 531nm

OpCast (Mean Absolute Error)

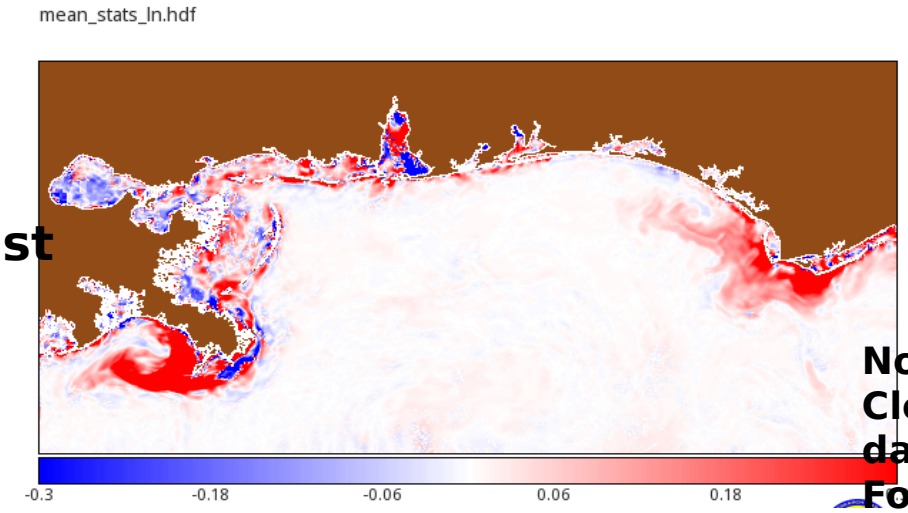


BioCast (Mean Absolute Error)



mae = |24 Hr Forecast – Next Day's Image|

Difference
OpCast – BioCast

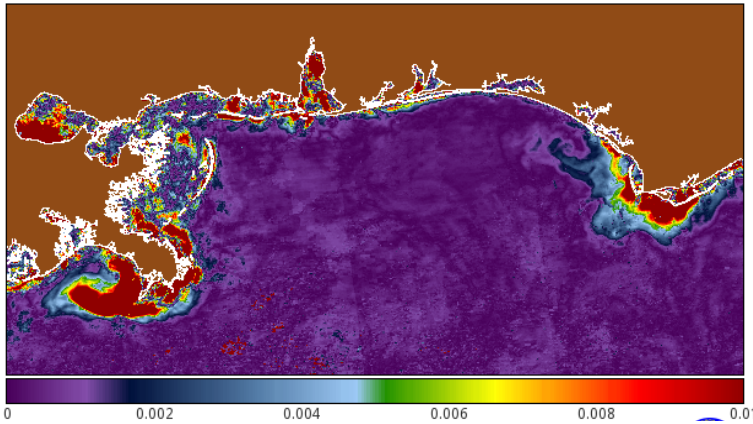


Red = BioCast performs better
White = OpCast & BioCast are similar
Blue = OpCast performs better.

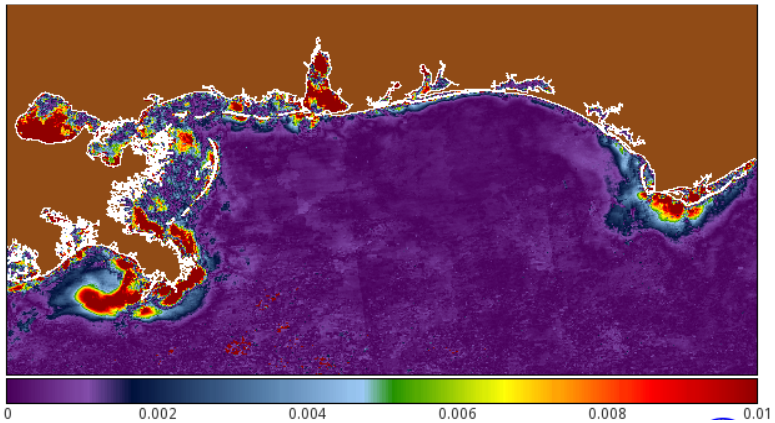
Note: Errors associated with Cloud filling using previous day's Forecast, flow fields and sources And sinks.

10 Month Mean Forecast Statistics
(December 2011 – October 2012)
MODIS-Aqua Backscattering Coefficient (c) @ 531nm

OpCast (Mean Absolute Error)

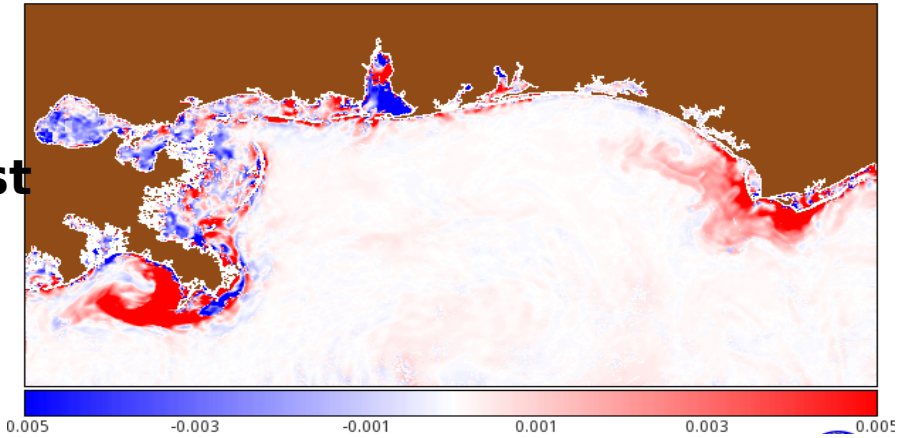


BioCast (Mean Absolute Error)



mae = |24 Hr Forecast – Next Day's Image|

Difference
OpCast – BioCast



Red = BioCast performs better

White = OpCast & BioCast are similar

Blue = OpCast performs better.


BATTLESPACE AWARENESS AND INFORMATION OPERATIONS
PMW 120


OCEANOGRAPHER
OF THE NAVY